CDR DEVELOPMENT PROJECT

A Sea Level Fundamental CDR from Reprocessing TOPEX Altimeter Data

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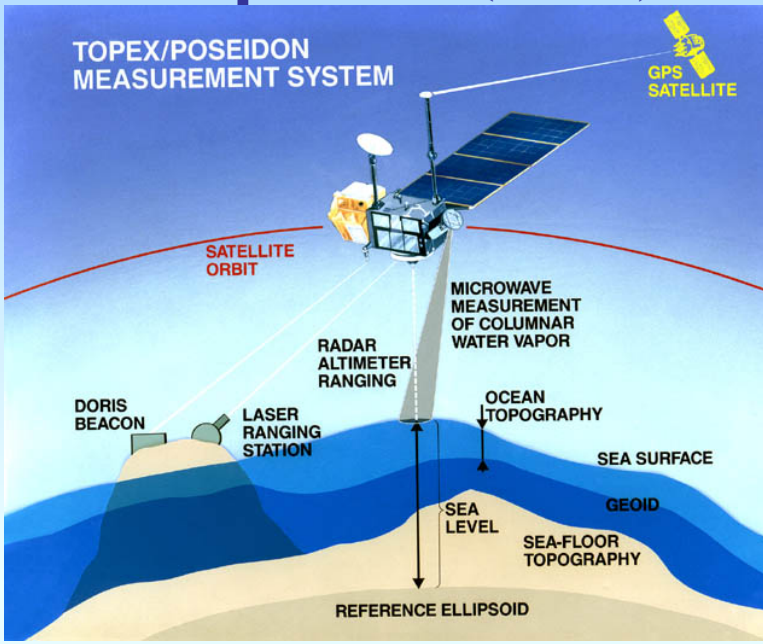
Outline

- Project Description
- Production and QA Approach
  - Note: CDRs are still under development
- Applications
- Status, Schedule, and Issues

Altimeter Sea Level Project Description (1 of 2)

- Fundamental Measurement: Sea Surface Height (SSH) from TOPEX altimeter measurements updated by retracking, improving microwave radiometer data, and using new orbits and ancillary information (new Jason GDR-D "standard")



- Time Period: January 1993 – October 2005
- Spatial Resolution: Repeating ground track (+/- 1 km, max lat = 66.0 deg). Along-track resolution ~ 6 km (1 sec, with SSH at 10/sec). Along-track points not aligned.
- Time Step: Orbit repeat = 10 days, 127 revs per repeat cyc
- Data Format: netCDF (translated from original fixed length binary records). Consistent with ongoing altimeter missions Jason-1/2 (newly current GDR-D).

Altimeter Sea Level Project Description (2 of 2)

- Inputs
  - TOPEX Sensor Data Record (SDR) for waveforms, Calibration data to re-derive PTRs, Geophysical Data Record for translation/ completeness (original data generated by project, archived at PODAAC)
  - Reprocessed TMR data (improved calibration, coastal resolution)
  - New Precision Orbits (POE)
  - New Ancillary Information: Atmospheric Corrections, Sea State Bias Model(s), Tides, Mean Sea Surfaces (MSS)
- Uncertainty Estimate
  - Total SSH error ~ 3 cm for global RMS
  - Main error sources: Altimeter noise (~1.5 cm), Sea State Bias (~1.0 cm), Orbit (1-2 cm), Atmospheric corrections (~1 cm)
- Output: Improved/calibrated Geophysical Data Record of Sea Surface Height with corrections
  - Ancillary fields included in each record
    - Altimeter measurement of Significant Wave Height (SWH), backscatter (sigma0 -> wind speed)
    - Microwave Radiometer measurement of atmospheric water
    - Geophysical Models: Tides, MSS, Inverted Barometer Effect

Project Description Table

CDR(s) (Validated Outputs)	Period of Record	Spatial Resolution; Projection information	Update Frequency / Data Time Step	Data format	Inputs	Uncertainty Estimates (in percent or error)	Collateral Products (unofficial and/or unvalidated)
Sea Surface Height (SSH)	January 1993 – October 2005	Repeating ground track +/- 1 km, 127 revs/ cycle. ~ 6 km along track.	Historical data. (SSH data record is being extended by Jason series) 10 day orbit repeat cycle. ~1 sec along track.	NetCDF (translated from GDR binary flat files)	TOPEX SDR (waveforms), GDR, Cal. Reprocessed TMR. New Precision Orbits (POE). New Ancillary data: Atmospheric corrections, Tides, Mean surfaces	SSH Global RMS ~ 3 cm. Altimeter noise ~ 1.5 cm, Sea State Bias ~ 1 cm, Orbit 1-2 cm, Atmospheric corrections ~1 cm.	Altimeter Significant Wave Height (SWH), surface backscatter (sigma0), Radiometer atmospheric water

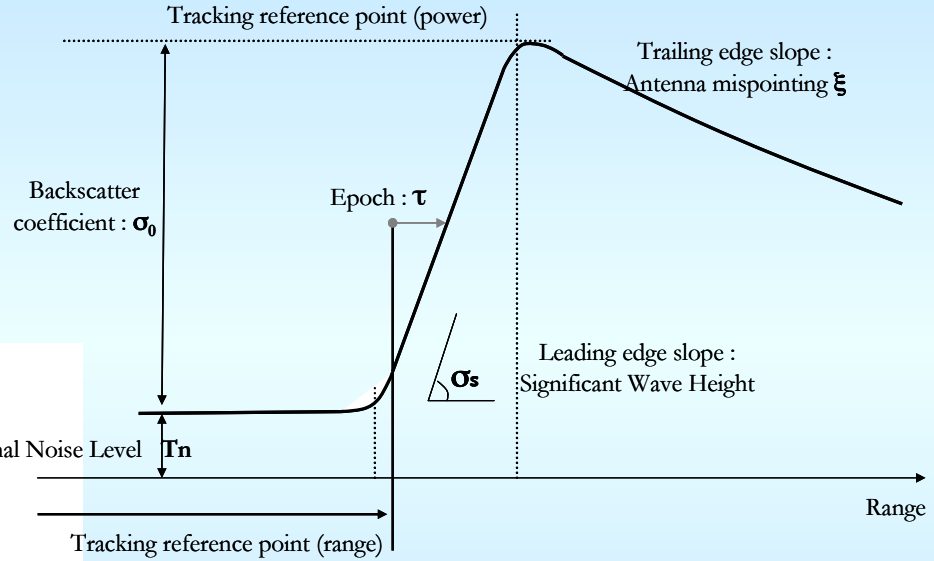
Production Approach (1 of 2)

- Retrack TOPEX data with revised instrument corrections for
  - Point Target Response (PTR) changes in Alt-A
  - Leakages in waveform (WF) that move with range rate
- Use improved processing of radiometer (TMR) data that improves calibration and coastal data
- Data Improvements (consistent with Jason GDR-D)
  - Precision Orbits (POE): provided by GSFC as part of ongoing altimeter activities
  - Geophysical Corrections/Ancillary Data
    - Atmospheric Pressure products (Dry Tropo, Inverse Barometer): provided by CNES
    - Tides, Mean Sea Surface: provided by OSTST members
  - With above improvements, solve for new Sea State Bias (SSB)
- CNES updating Jason data, but not TOPEX

Production Approach – Retracking (2 of 2)

- Instrument corrections needed for TOPEX data
  - Changes in PTR for Alt-A with time cause changes in range and significant wave height (SWH) – range (SSH) is key problem for CDR
  - Leakages in waveform (WF) that move with range rate

- Return signal Waveform results from convolution of Radar PTR, surface height distribution, flat surface response function. ➔



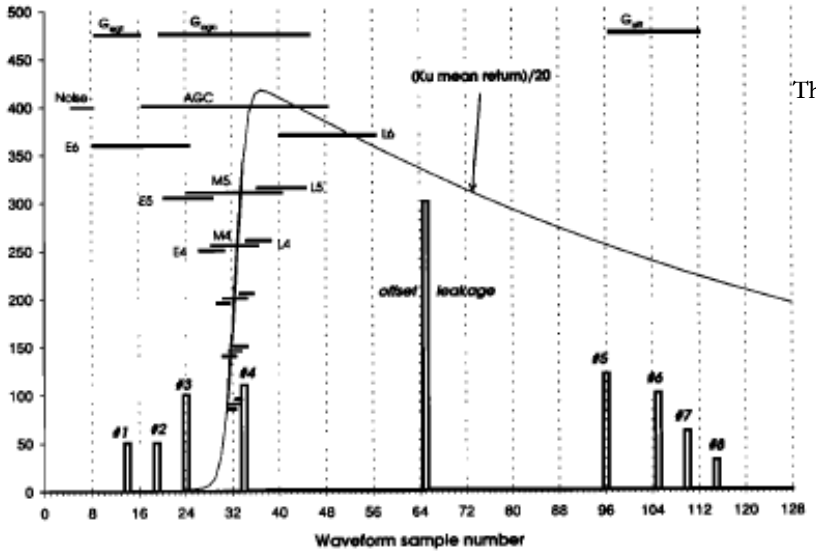


Figure 6. TOPEX Ku altimeter gates, mean return, and center locations of waveform leakage spikes.

↑ "Retracking" is solving for the parameters in the waveform model: Range/Epoch, Amplitude/Power (sigma0), Slope (SWH), Antenna Pointing, Noise

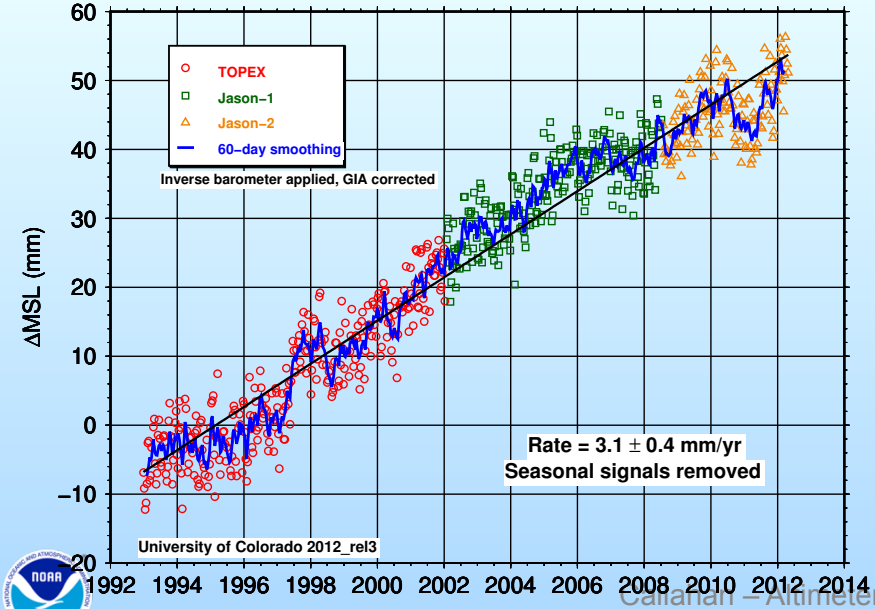
← Leakages (x20) from Hayne et als, 1994, JGR 99, 24,941.

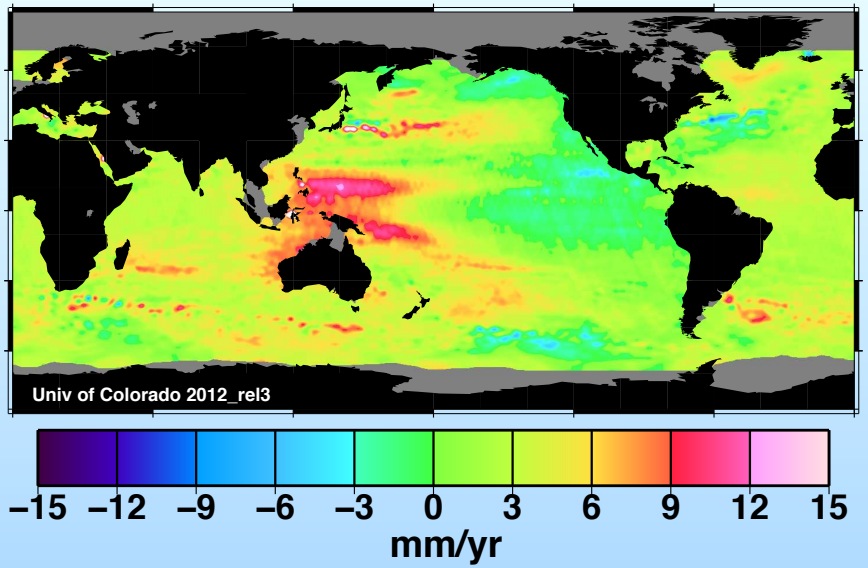
Quality Assurance Approach

- Development
  - Simulations and detailed analysis of waveform residuals used to assess accuracy of processing, fitting
  - Samples through the entire 13 year record will be processed and compared to previous versions, assessed for presence/absence of expected/ unexpected trends
  - Focus on overlap period with Jason-1: ~7 months in same orbit ~70 sec difference along-track
- Production data will be evaluated for each 10 day cycle
  - Plots and statistics for each cycle for key quantities – Residual SSH, SWH, Sigma0, Good/Flagged points
  - Consistency with global sea level trend

Applications

- NOAA Vision for Climate – An informed society anticipating and responding to climate and its impacts
  - Mission: To understand and predict changes in climate, weather, oceans, and coasts
  - Long-term Goals: Climate Adaptation & Mitigation; Weather-Ready Nation; Healthy Oceans; Resilient Coastal Communities & Economies
- Main uses of high accuracy, long term altimetry data are
  - Development of ocean modeling to approach weather forecasting capabilities. Increase understanding of ocean circulation and changes. Leads to coupled ocean-atmosphere, ocean-biological models
  - Climate studies of sea level rise globally and regionally – reflects both ice melting, ocean heating and, regionally, winds. 1 mm/yr sea level accuracy requires certainty to < 1 cm over 10 yrs. (Diagrams below from http://sealevel.colorado.edu/)
    - Online viewer of coastal sea level height effects: http://flood.firetree.net/



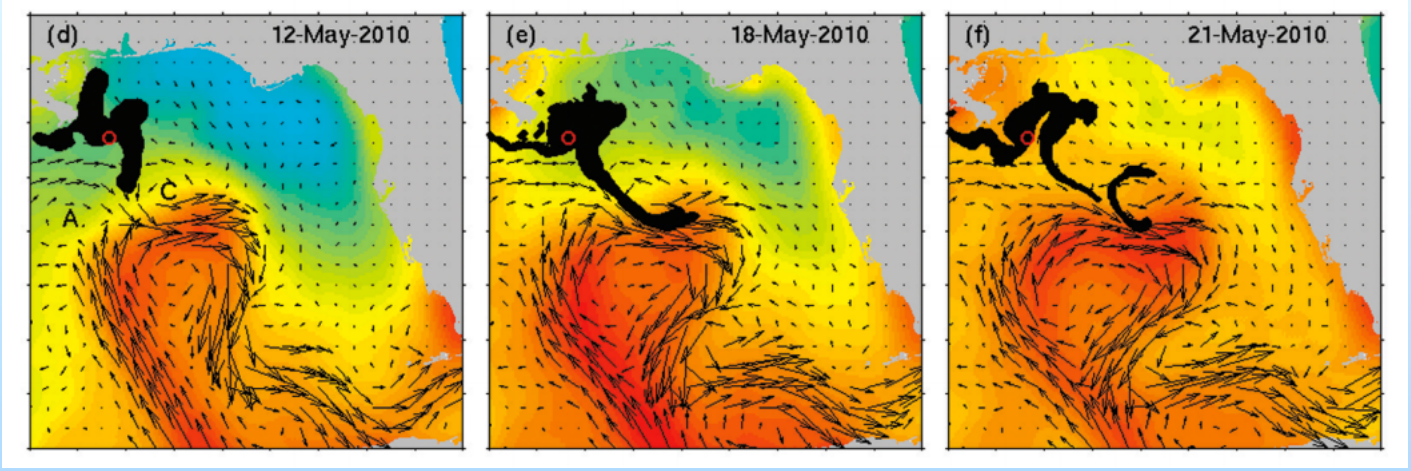


Applications

- Uses for Near Real Time Altimetry
  - See http://sealevel.jpl.nasa.gov/science/ -> Societal Benefits http://www.aviso.oceanobs.com/en/applications/index.html
  - Mesoscale eddy tracking for naval, oil rig, fishing, shipping operations; hurricane intensification over warm eddies; **pollution tracking (e.g., oil spills)**; sport sailing
  - Inland water level tracking (retracked data may improve)

"Evolution of the Loop Current System During the Deepwater Horizon Oil Spill Event as Observed With Drifters and Satellites", Yonggang Liu, Robert H. Weisberg, Chuanmin Hu, Charles Kovach, and Rolf Riethmüller, pp 91-101 in Monitoring and Modeling the Deepwater Horizon Oil Spill: A Record-Breaking Enterprise Geophysical Monograph Series 195. Copyright 2011 by the American Geophysical Union. doi:10.1029/2011GM001127.

Current models (vectors) included satellite altimeter data.



Applications

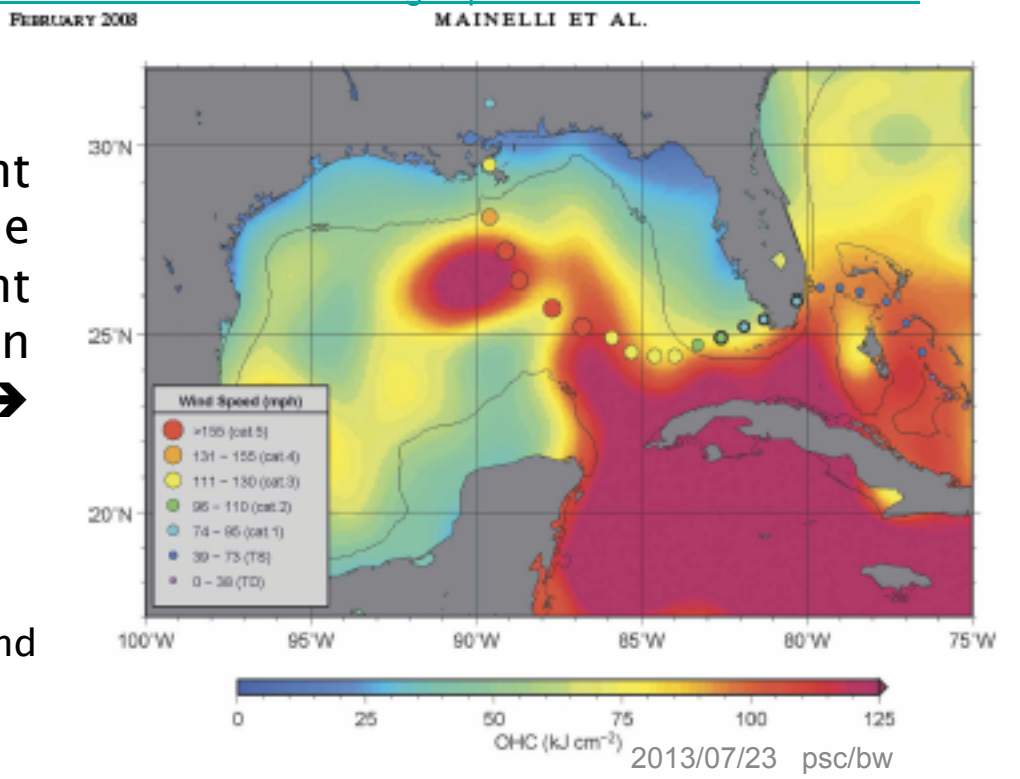
- Uses for Near Real Time Altimetry
  - Mesoscale eddy tracking for hurricane intensification over warm eddies

"Hurricane Sandy was a tremendous thunderclap," said Laury Miller, satellite altimetry chief for the U.S. National Oceanic and Atmospheric Administration (NOAA) in Washington. "It opened everyone's eyes to the possibility of massive dislocation and emphasized the critical need to plan for future storms."
Initiatives like the one proposed for New York to mitigate the impact of storms rely heavily on space-based altimeters to aid in forecasting severe weather and monitoring the rising sea levels that can heighten the impact of hurricanes and tropical storms. (Copyright 2013 SpaceNews online at http://www.spacenews.com/article/features/35832earth-science-and-climate-monitoring-superstorms-drive-home-need-for-sea#.Ue7iO2T8mjI)

Tropical Storms and Ocean Content
Ocean heat content and Hurricane strength for Katrina. Heat content is much more concentrated than SST ➔

from

"Application of Oceanic Heat Content Estimation to Operational Forecasting of Recent Atlantic Category 5 Hurricanes", MICHELLE MAINELLI et als, 2008, Weather and Forecasting, 23, 3-16, DOI: 10.1175/2



Status, Schedule, and Issues

- Status
  - Making excellent progress on waveform leakage and PTR investigation
  - Revisited estimation approaches (LSE, MLE, MAP, fitting in dB) – improvements marginal because of leakages
  - Investigating usable portion of Calsweep/Cal1(for PTR and leakage modeling vs time)
  - Investigated APL (Jensen) model (phase imbalance between I/Q channels)
  - Began investigating estimating PTR from on orbit data over flat, stable targets (e.g., lakes; land too noisy)

- Near-term Plans (needs further update from new task plan)
  - Progress consistent with expenditures. 1 year extension in revised plan.
  - Complete investigation of PTR fitting, leakage effects, 59-day variations (Dec '13)
  - Process set of test cycles to check corrections, procedures, common netCDF data format (Jan '14)
  - Development error estimates and QA procedures (Mar '14)
  - Develop process for determining SSB and begin use (June '14)
- State any risks or concerns
  - Several inputs come from outside sources:
    - Updated Precision Orbits from GSFC
    - Updated atmospheric correction files from CNES (have contacted and have verbal commitment)

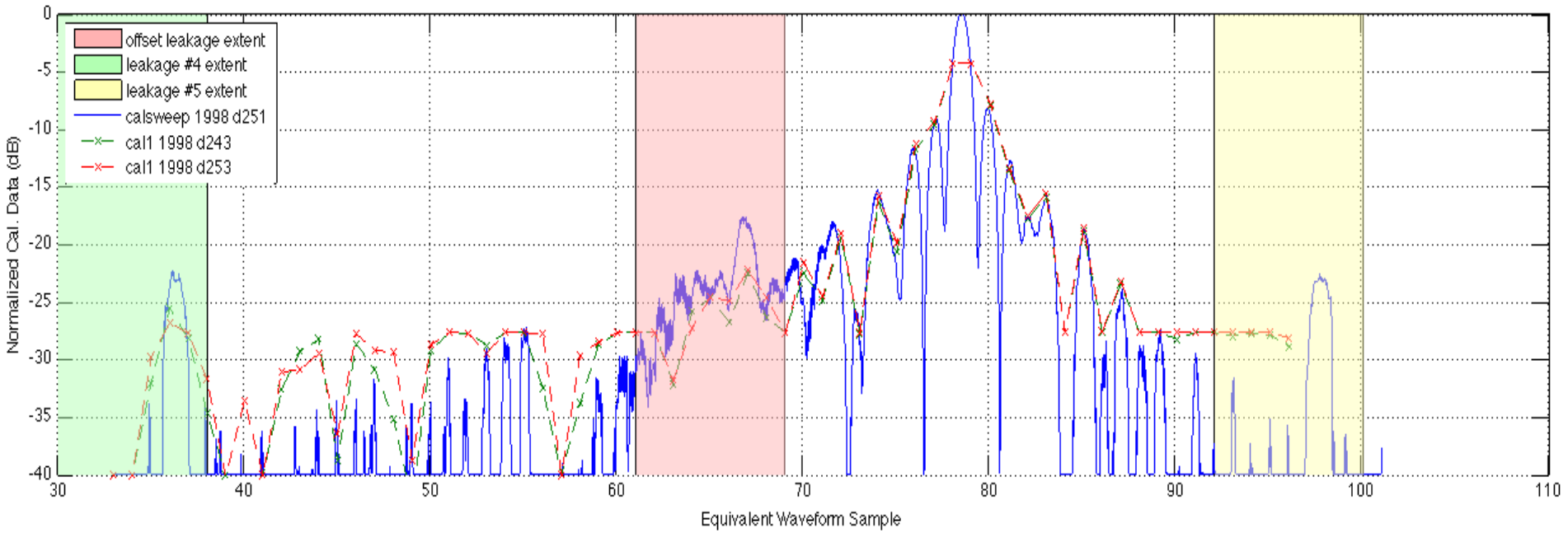
BACKUP

Status Details

- Revisited estimation approaches (LSE, MLE, MAP, Bayes, fitting in dB)
  - All are biased, some (MLE, MAP, Bayes) have lower variance estimates
  - With leakages, improvements are marginal and may not merit code rewrite and testing
  - Stick with least squares estimation (LSE), but possibly use dB
- Investigated APL (Jensen) model (phase imbalance between I/Q channels)
  - PTR changes significantly with location of point target (waveform sample)
  - Not shift invariant PTR—impractical to model
- Investigating usable portion of Calsweep/Cal1
  - Only first few lobes seem reliable, but waveforms are sensitive to 20 or 30 lobes (must model far side-lobes blindly)
  - Leakages apparent—can model most important leakage vs time from cal1 data

Status Details

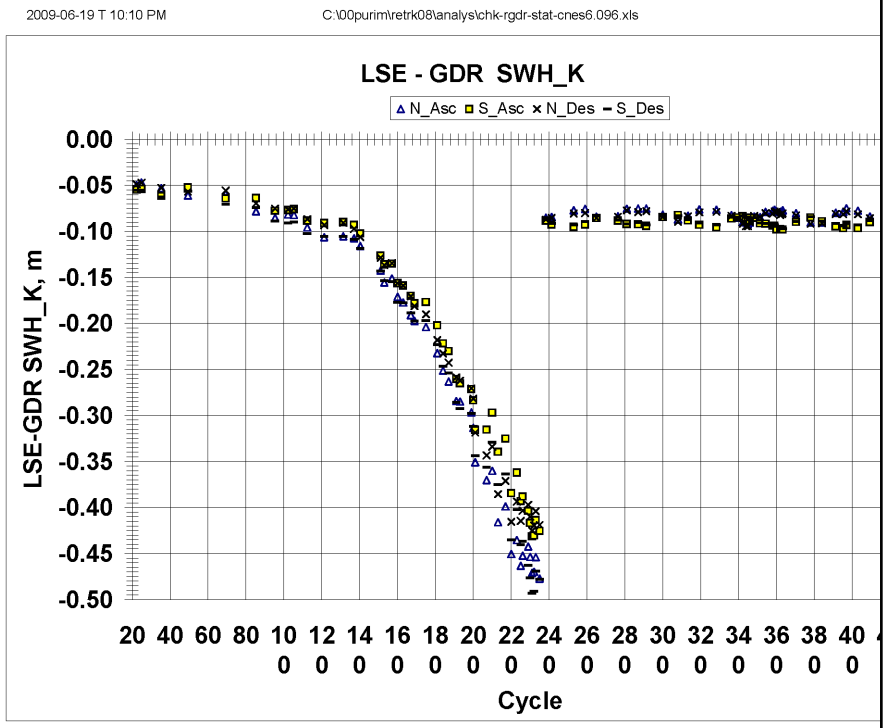
- Identify usable portion of Calsweep/Cal1 for determining PTR, particularly changes in Alt-A
  - Cal1 and Calsweep seem contaminated by leakages
  - Far lobes seem unreliable (Cal1 and Calsweep disagree)
  - Leakage #4, the most important leakage since it is near the tracker center bin, is apparent in the Cal1 data and can be modeled as a function of time

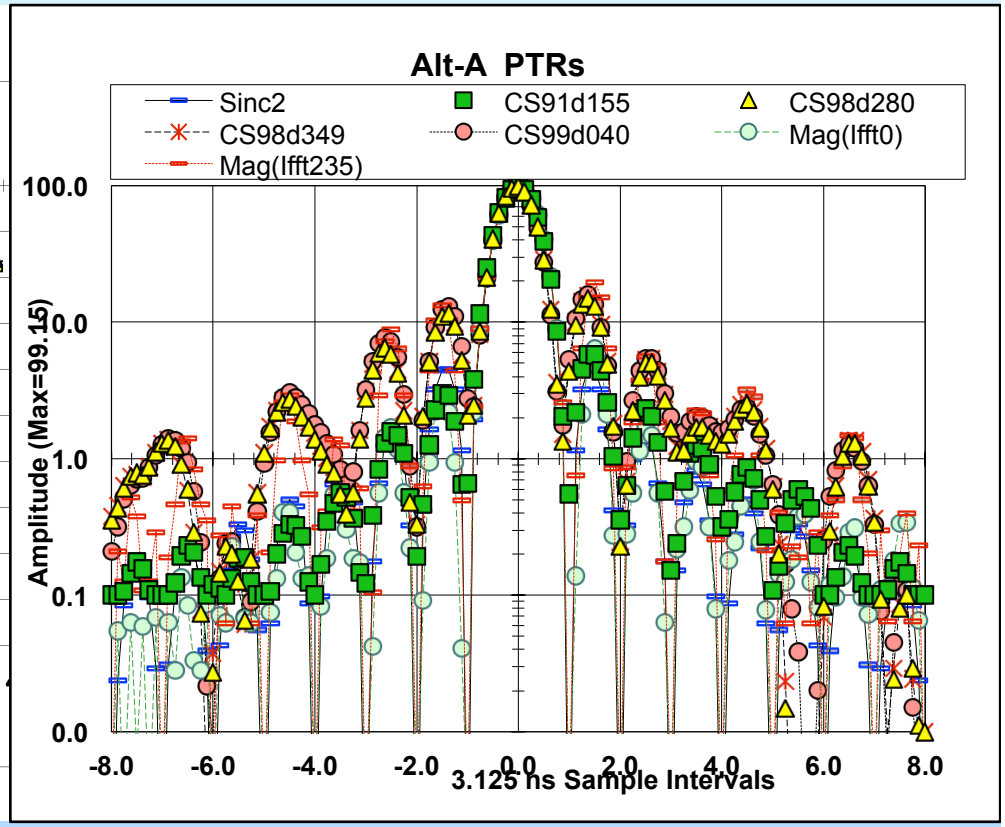


Production Approach – Retracking (3 of 3)

- Instrument corrections needed for TOPEX data
  - Point Target Response (PTR) changes in Alt-A

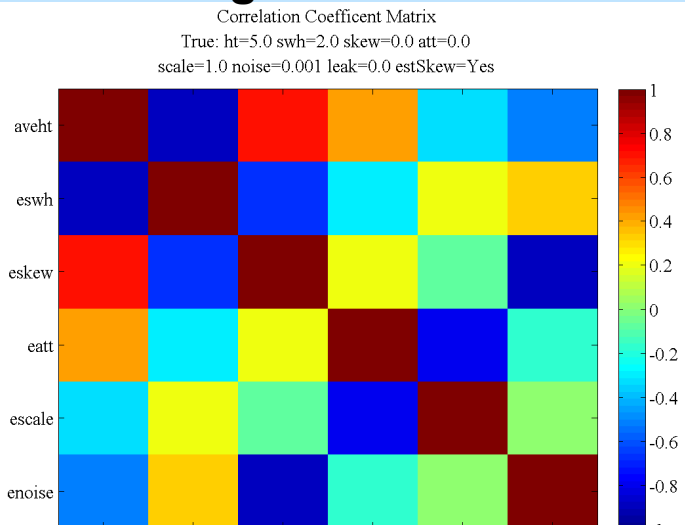
Changes in PTR (right) – increase and distortion of sidelobes – caused changes in SWH (and range) that are corrected when the actual correct PTR is used in processing. Change in SWH also changes Sea State Bias (SSB) correction used.

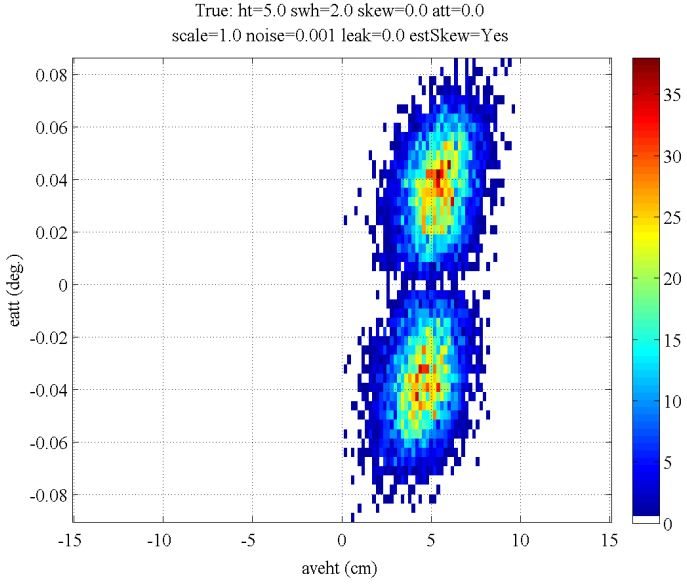




Simulation Results

Parameter Correlation Solving for Skewness





All: SWH = 2 m
Att = 0
Skew = 0
dH = 5 cm

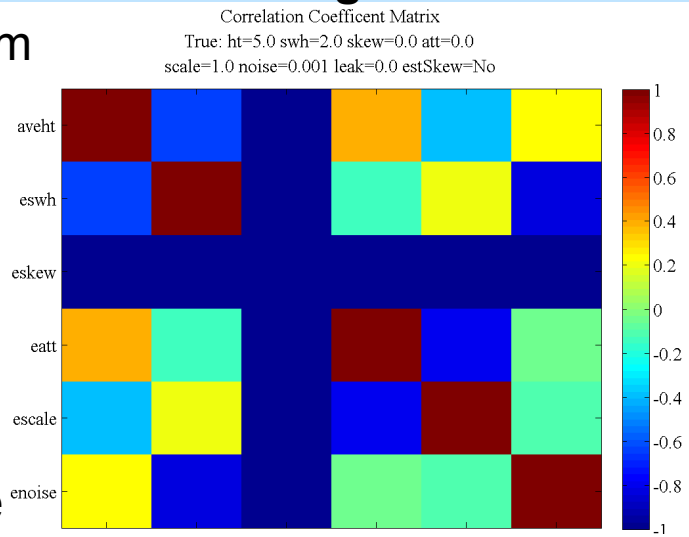
Params:
dH, SWH,
Skew, Att,
Scale, Noise

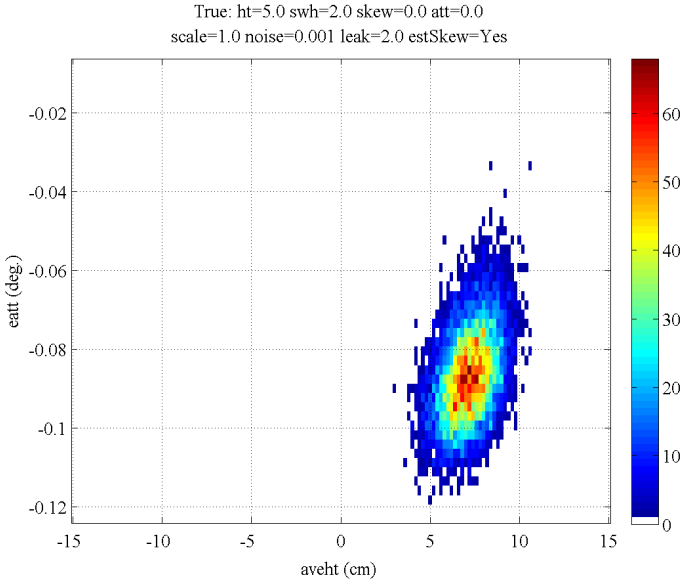
← Leakage = 0

Leakage = 2X →

2D Histogram:
Att / dH

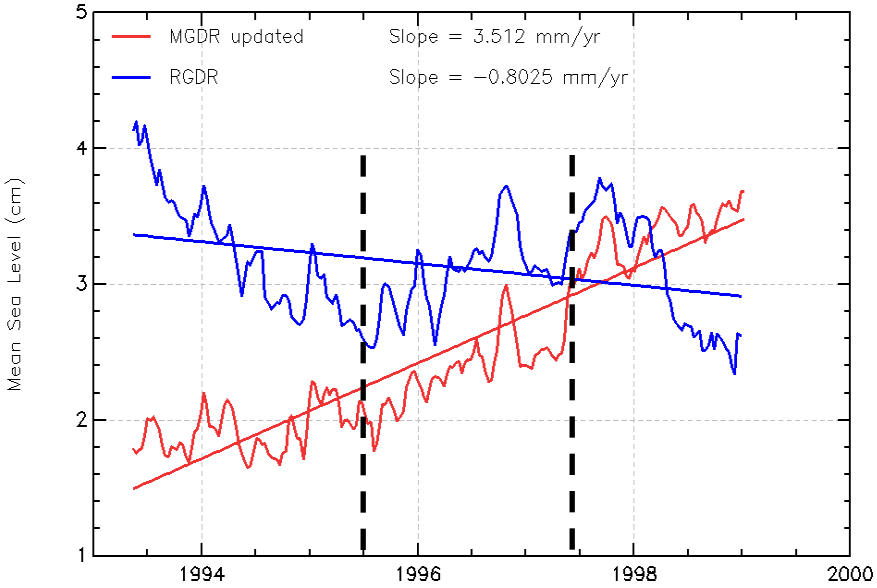
Parameter Correlation Not Solving for Skewness



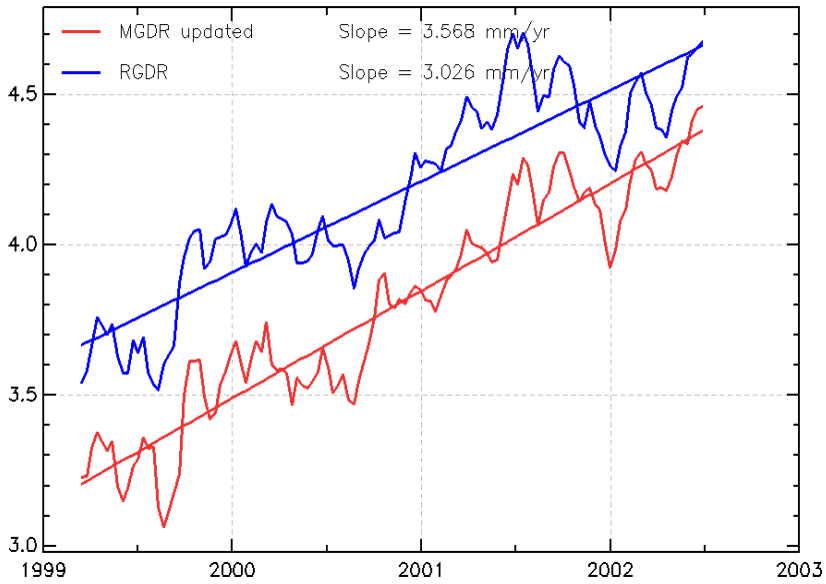


Mean Sea Level Analysis by S. Labroue (CNES) '09 OSTST

Side A MSL



Side B MSL



• Side A MSL with RDGR shows strong discrepancy with respect to MGDR MSL. RGDR exhibits a false curve and trend (-0.8 mm/year!!!!). The main differences appear at the beginning and the end of the time series.

• Side B MSL with RGDR data presents a trend lowered by 0.55 mm/year which is significant for MSL studies. We are more confident in MGDR MSL since side B is very stable (validated against in situ data and Jason-1 data)

Careful assessment of the PTR correction needs to be performed on the SSH (including PTR corrections on range and SWH (through SSB)). A SSB has been estimated on RGDR products for each altimeter.